Comment on an Enigmatic Star, UU Her(Proceedings of the Workshop on the Activities and Ejecta of Supergiant Stars)

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The UU Her stars are now believed as pulsating less massive stars. The discovery of double-periodicity for UU Her, once regarded as the type of this group, emphasizes again a serious question on the nature of this star. The period-ratio, the pulsational instability, and the strength of coupling together with the hydrodynamic model will be investigated for UU Her based on new opacities.

§1. UU Her Stars

As discussed in this workshop, there are interesting semi-regular variable stars at the upper domain of the HR diagram. The UU Her stars are a group of them. V441 (=89 Her) and V814 Her (=HD 161796) which are typical members of this group are F-type supergiant stars and show semi-regular variability. These stars were classified by Sasselov[1] based on their high Galactic latitude and unusul light variability. The variability of spectral line profiles also mentioned as the characteristics of these stars. The irregular stellar variability will be explained from their less massive nature, because the low surface-gravity stellar models can show aperiodic pulsation caused from the nonlinearity of single-mode pulsation[2]. The infrared emission of these stars are evidence for substantial mass loss which should reduce the stellar masses.[3] Thus the stars can be discussed as the candidate for the central star of planetary nebulae.

§2. The Double-Periodicity of UU Her

It should be stressed that the star UU Her, which was thought as the type of this group, is not identified as any IRAS point sources. And moreover, Zoldos and Sasselov[4] found that the light variation of UU Her is resolved into two main periods: 0.013785 Hz and 0.022302 Hz (72.543 and 44.839 in days), or 0.011151 Hz and 0.013785 Hz (89.678 and 72.543 in days). The amplitude variations of both modes are found. Alternative enhancement of amplitudes may express the exchanges of pulsation energy between these modes. Even though it is not so clear that other UU Her type stars could show such a double-periodicity, the double-mode behaviour is an objection to the low-mass hypothesis for UU Her.

The usual first step to study double-mode variable stars is to calculate pulsation periods and pulsational instability with observed surface temperature. Reasonable masses and luminosities should be assumed with appropriate chemical composition. After such a procedure, we may find the pulsational mass as the function of the assumed luminosity. The coupling coefficients will be also estimated by some procedures to check the possibility of double-mode pulsations. Next step is to construct hydrodynamical models to compare with the observational light variation.

Since new opaciteis OPAL has been published[5], the models should be constructed by using these opacities. The effect of convection may be studied carefully to estimate the strength of coupling.[6] For hydrodynamic models the convection is also necessary to study the shock-like phenomena accompnied with negative pressure gradient and negative radiative flux carefully.[7] We must mention here Cardelli's report[8] that UU Her is metal poor, [Fe/H]≈ -1.

Unfortunately, we have no references fulfilled the above requirement at the present time. We may estimate the pulsation properties using old results. we suppose that the modes were the fundamental mode and the first overtone mode. Then the period ratio 0.60 ($\approx$ 44.84 / 72.54) fits a high luminous model in the Cepheid Instabilty Strip calculated by Takeuti and Petersen[9]. The paprameters of the model are as follows: $M/M_{\odot}$ is 16.6, $L/L_{\odot}$, 56900, $R/R_{\odot}$, 330, and T_{eff}, 4930 K, respectively. The surface temperature is that of early K-type. The period is approximately 80 days. The period fits the observed one, but the temperature does not fit the observed spectral type F. The gravity is $\log g = 0.6$ in c.g.s. units. The period ratio 0.83 is too high to fit any reasonable models in their sequence.

§3. Enigma

While UU Her seems to be a luminous supergiant star, the double-mode behaviour is found among short-period, less luminous cepheids. The coupling is weak for also such a model. This means that the envelopes of UU Her is not similar to those of high luminous cepheids. And moreover, the metal poorness is also constraint with the high luminosity. It is urgent to study the pulation properties of F-type supergiant stars based on new opacities, because the Takeuti-Petersen models are based on old ones with the Population I chemical composition. The systematic survey of coupling coefficients is also important.

The double-periodicity and the low metalicity are likely evidence for low-luminous nature. Then UU her would seem to be a less massive Population II star. In this case, we might have to explain the low value of period ratio based on nonlinear theory. Phase-locking will be possible, but the clear double-periodicity itself can be transient. It is not so easy task to resolve the problem.

References

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